Corrosion Potential Monitoring for Polymer Composite Wrapping and Galvanic CP System for Reinforced Concrete Marine Piles

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Project Sponsors

DoD Corrosion Prevention and Control

- Office of Under Secretary of Defense, Office of Corrosion Policy and Oversight
- Deputy Assistant Secretary of the Army Acquisition Policy and Logistics
- Assistant Chief of Staff for Installation Management
- Headquarters, U.S. Army Installation Management Command

DoD Corrosion Problem

- Piers and wharves
  - Critical facilities
  - $14.5M maintenance costs
  - Reinforced concrete piles
- Aged and deteriorated
  - Rebar corrosion
  - Spalling concrete

Repair Options

- Patching
- Polymeric composite wraps
- Pre-fabricated composite shell with CP

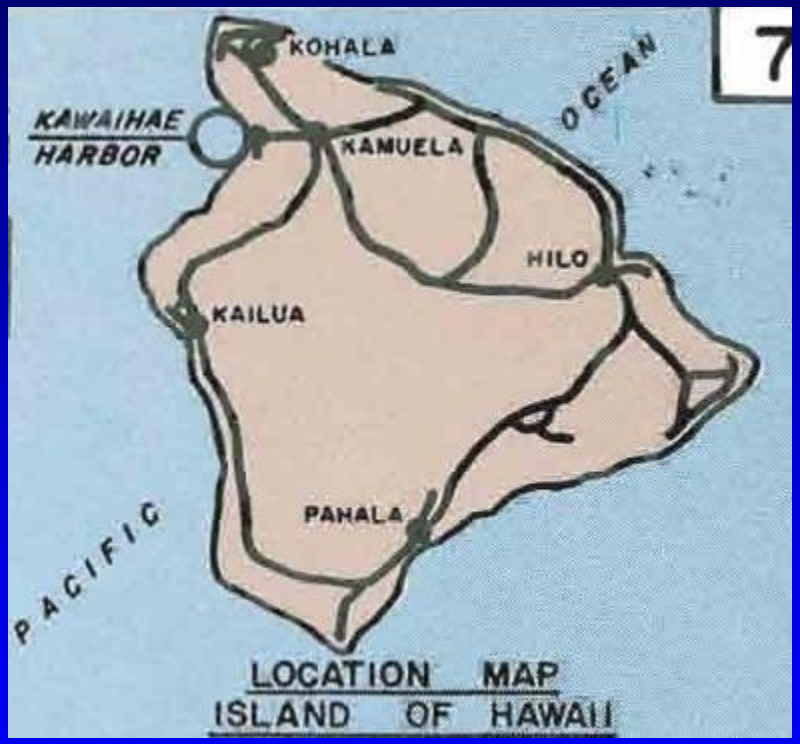
Objective

- Demonstrate and implement innovative technology that provides corrosion protection and impact resistance to reinforced concrete piles in marine environments

- FRP Composite wrap with galvanic CP protection

Demonstration Site

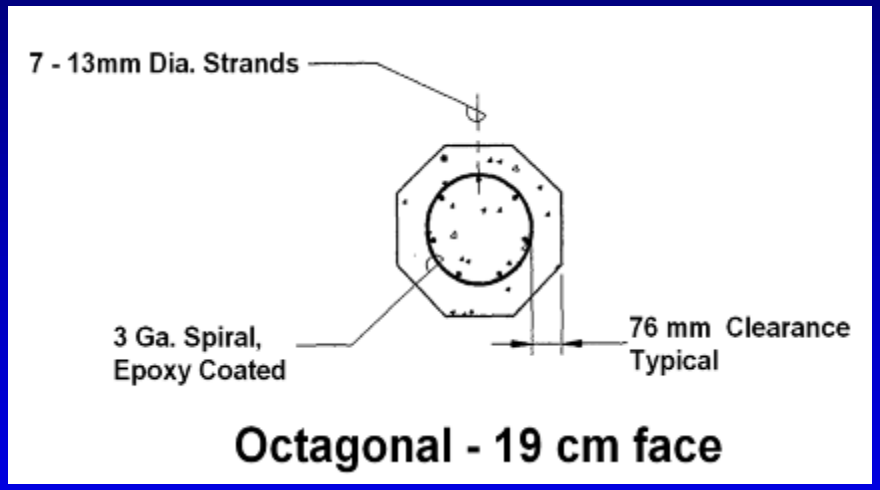
Kawaihae Harbor Dolphin Piers

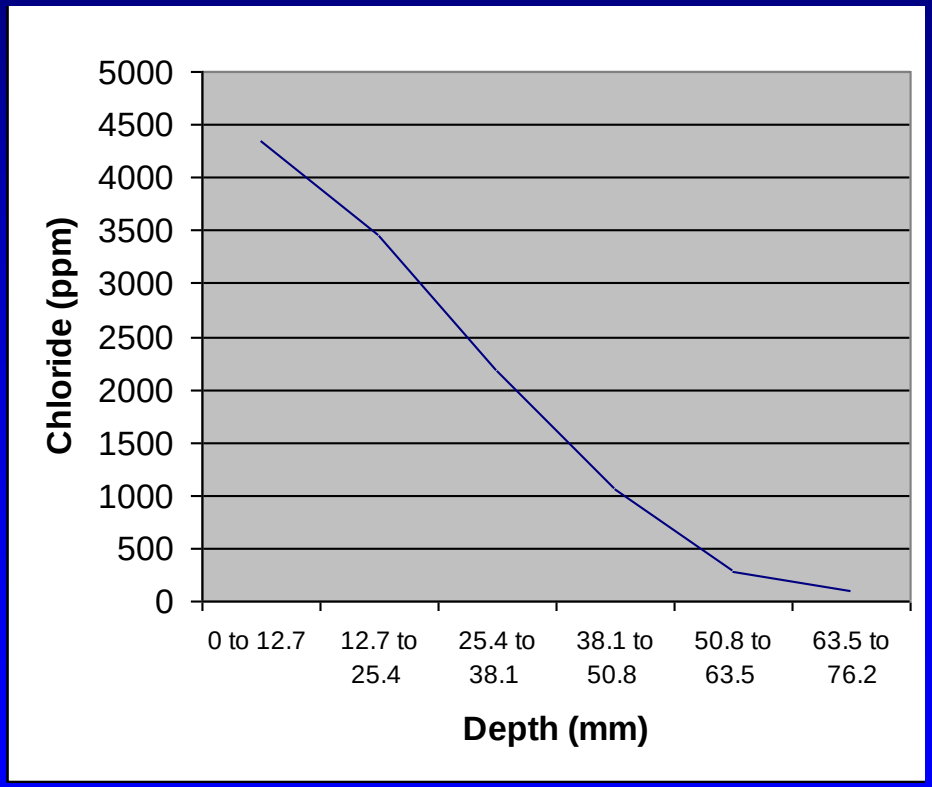


Demonstration Site

Kawaihae Harbor Dolphin Piers

Pre-Cast Steel Reinforced Concrete Piles





Demonstration Metrics

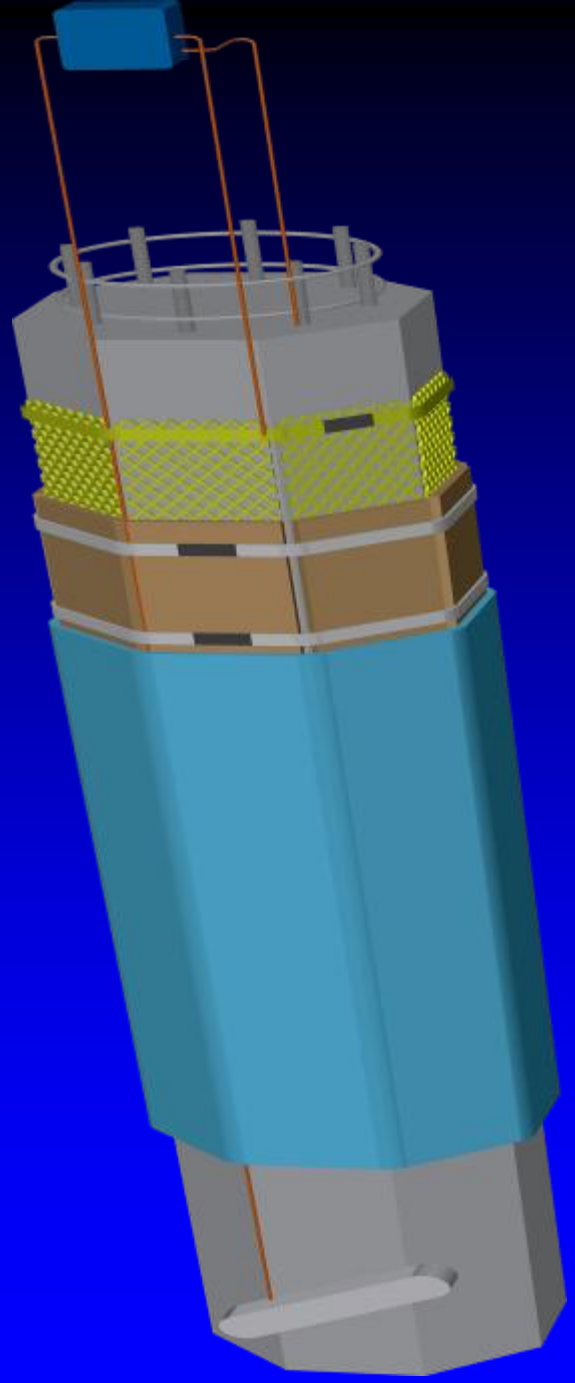
- FRP composite pile wrapping
  - Field applied, commercially available
  - Underwater installation
  - Splash zone application *(2.4 meters)*
  - Impact and abrasion resistance
- Galvanic cathodic protection system
  - Integrated anode within wrapped section
- Corrosion potential monitoring

System Design

- **Expanded mesh zinc anode**
- **Composite board compression panels**
- **Woven glass fiber wrap**

Nominal Thickness	0.685 mm
Tensile Strength	32.8 x 10^4 kN/m^2
Tensile Load, per ply	580 kg
Comp. Strength	17.2 x 10^4 kN/m^2

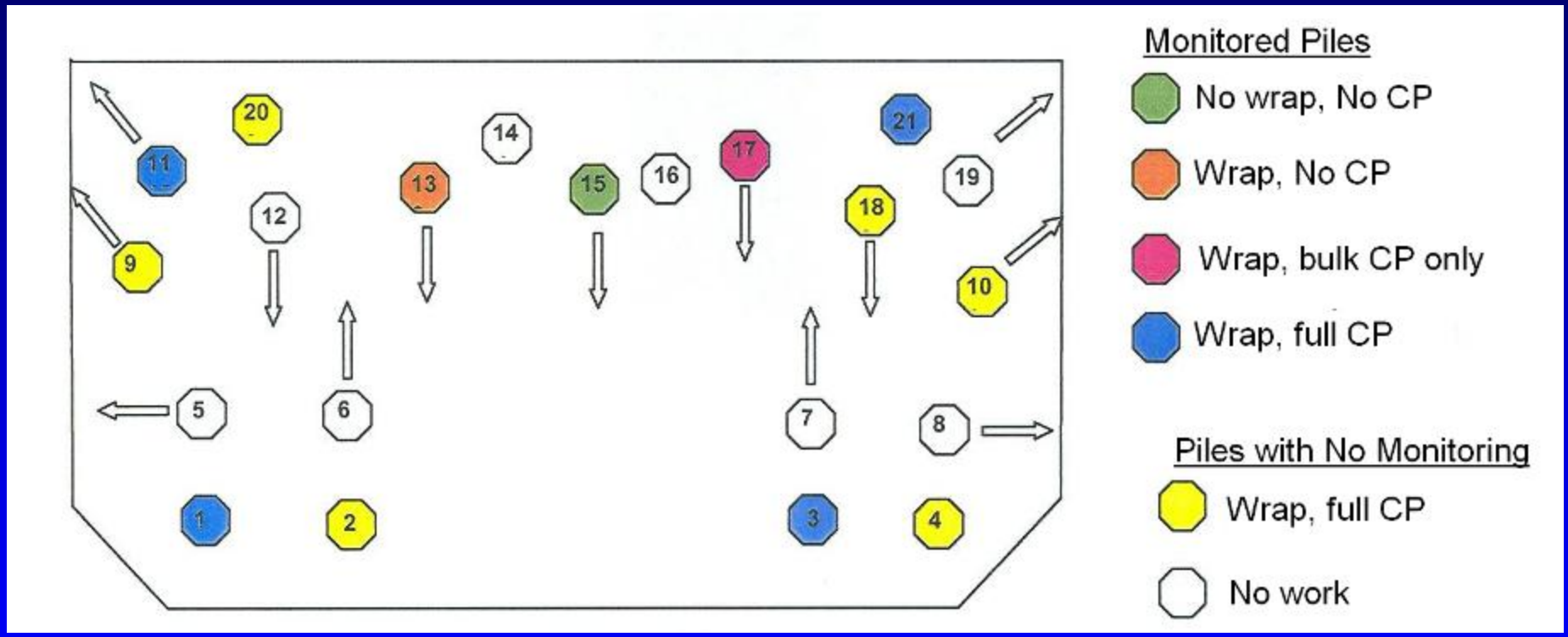
- **Bulk zinc anode**



Corrosion Monitoring System

- Silver/silver chloride reference electrodes
  - Three locations per pile
  - Cables protected with PVC conduit
- Remote Monitoring Unit (RMU)
  - Onboard software & data storage backup
  - Instant off, depolarisation measurements
  - PV-powered data transmission
- Shore-side Main Control Unit (MCU)
  - Radio transmission from RMU
  - Data storage
  - Land line accessibility

Dolphin #2 Piles



System Installation

- Work restricted to low tide
- Interruptions
  - planned
  - Unplanned
- Dive Crew Coordination

Shore Side Preparation

Zinc Mesh Anode /Compression Panels / Electrode Calibration

System Installation

Bulk Zinc Anode Attachment and Surface Cleaning

System Installation

Setup

System Installation

Electrical Continuity & Steel Connections

System Installation

Electrical Continuity & Steel Connections

System Installation

Patching & Securement of Cables

System Installation

Zinc Mesh Anode & Compression Panels

System Installation

Zinc Mesh Anode & Compression Panels

System Installation

Composite Wrap

System Installation

Composite Wrap

System Installation

Electrical Wiring and Monitoring System

System Installation

Electrical Wiring and Monitoring System

System Installation

Electrical Wiring and Monitoring System

System Installation

Commissioning & Performance Monitoring

- Baseline readings of reference electrodes
- Reporting of monthly corrosivity potential data
- 6, 9, 12 and 15 month inspection of RMU / MCU components
- Four-Year evaluation

Dolphin #3

Time Zero – Baseline Data

Pile #18: Wrap with integrated CP and bulk CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	-0.562	-0.752	-0.433
Native Potentials	-0.407	-0.444	-0137
Current Output			
System	0.562 amps		
Bulk Anode	0.534 amps		
Mesh Anode	0.270 amps		

Pile #14 - Wrap with no CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	n/a	n/a	n/a
Native Potentials	-0.385	-0.508	-0.503
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

Pile #17: Wrap with bulk CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	-0.349	-0.794	-0.787
Native Potentials	-0.317	-0.366	-0.370
Current Output			
System	0.505 amps		
Bulk Anode	n/a		
Mesh Anode	n/a		

Pile #16 - Control, no wrap and no CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
Instant On	n/a	n/a	n/a
Native Potentials	-0.629	-0.629	-0.431
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

Dolphin #3
1 Month Data

Pile #18: Wrap with integrated CP and bulk CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.678	-0.878	-0.815
Instant Off	-0.665	-0.820	-0.761
IR	0.013	0.058	0.054
Native Potentials	-0.407	-0.444	-0.137
Polarisation	0.258	0.376	0.624
Current Output			
System	n/a		
Bulk Anode	0.103 amps		
Mesh Anode	0.077 amps		

Pile #14 - Wrap with no CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.412	-0.484	-0.478
Instant Off	n/a	n/a	n/a
IR	n/a	n/a	n/a
Native Potentials	-0.385	-0.508	-0.503
Polarisation	n/a	n/a	n/a
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

Pile #17: Wrap with bulk CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.638	-0.917	-0.905
Instant Off	-0.637	-0.909	-0.900
IR	0.001	0.008	0.005
Native Potentials	-0.317	-0.366	-0.370
Polarisation	0.320	0.543	0.530
Current Output			
System	n/a		
Bulk Anode	0.110 amps		
Mesh Anode	n/a		

Pile #16 - Control, no wrap and no CP

On Potentials	Ref. Cell #1 (v)	Ref. Cell #2 (v)	Ref. Cell #3 (v)
On	-0.395	-0.480	-0.478
Instant Off	n/a	n/a	n/a
IR	n/a	n/a	n/a
Native Potentials	-0.629	-0.629	-0.431
Polarisation	n/a	n/a	n/a
Current Output			
System	n/a		
Bulk Anode	n/a		
Mesh Anode	n/a		

Conclusions

- An innovative polymer composite pile wrapping system with integrated CP was demonstrated on two structures
- Initial data collection indicates proper operation of CP system
- Data acquisition has posed some preliminary problems. System currently undergoing upgrade

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Questions ?